47th Meeting of the HL-LHC Technical Coordination Committee – 08/03/2017

Participants: C. Adorisio, A. Apollonio, G. Arduini, M. Bajko, I. Bejar Alonso, F. Bertinelli, L. Bottura, C. Bracco, R. Bruce, O. Brüning (chair), H. Burkhardt, R. Calaga, S. Claudet, R. De Maria, B. Delille, B. Di Girolamo, P. Ferracin, P. Fessia, E. Hatziangeli, R. Jones, H. Mainaud Durand, P. Martinez Urios, M. Martino, R. Martins, E. Metral, M. Modena, M. Morrone, Y. Papaphilippou, D. Perini, S. Redaelli, A.Rossi, L. Rossi, S. Sadovich, L. Tavian, R. Veness, D. Wollmann, M. Zerlauth.

Excused: -

The slides of all presentations can be found on the website and Indico pages of the TCC.

O. Brüning recalled the action from the 46th HL-LHC TCC, chaired by M. Zerlauth, concerning a further update of the studies on the most credible cryogenic incident by T. Otto, foreseen for June 2018. The minutes were approved.

Summary of HL baseline and status of ECR approval, I. Bejar Alonso – slides1 , slides2, slides3, slides4

I. Bejar Alonso presented four ECRs for approval at the HL-LHC TCC.

The first ECR is from WP12 and regards the modification of the beam screen design for the triplet, required due to the high forces experienced during quenches with the CLIQ protection system. The document summarizes the cost implications (additional 250 kCHF) of the change and states that no impact is expected on other WPs and magnet field quality, as reported by M. Morrone.

O. Brüning recalled the discussions from the HL general meeting in Madrid concerning the effect of alignment errors. M. Morrone explained that this was addressed in detail with simulations, O. Brüning suggested adding a reference to these studies in the ECR.

L. Rossi asked what is the status of the analysis of CLIQ protection for the triplets. P. Ferracin explained that it is still under study, but there's certainly interest to have CLIQ, which provides significant advantages in terms of protection and reduction of MIITS and hot spot temperatures. L. Rossi asked if the budget for the change of the beam screen design, which is mainly coming from the purchase of additional material, could be kept until CLIQ is approved. M. Morrone mentioned that the budget could be kept on hold for a few months. P. Ferracin agreed and added that the effects of CLIQ on the beam screen will be tested on a triplet short model in June. The test will be instrumented to measure the induced deformation and to

check the impact on the performance of the model. G. Arduini asked if any impact should be expected on field quality due to the use of the beam screen alloy. M. Morrone explained that no issues are expected as this material was developed not to affect field quality, but that magnetic measurements will be carried out during the test to confirm this. P.Fessia confirmed that the same material has been used for the LHC beam screen as well.

I. Bejar Alonso concluded that the ECRs can be approved with the condition that the outcomes of the test in June should be verified.

ACTION: WP3 and WP12 should give a presentation in July on the outcomes of the short model tests and the impact on the beam screen of the CLIQ protection system.

The second ECR concerns the decision, already presented in TCC, of not having cryogenic BLMs and to redefine the scope for beam profile measurement devices to allow two final versions of beam gas vertex detectors to be installed in LS3 as part of the HL-LHC baseline. O. Brüning stated that the TCC approves the ECR.

The third ECR regards the increase of scope of WP17, including the cost increase for the CMS storage platform. O. Brüning stated that the TCC approves the ECR.

The fourth ECR summarizes the update of the HL beam parameters, provided by WP2. G. Arduini recalled the only comment received on the ECR by M. Pojer, concerning the duration of the ramp-down. G. Arduini confirmed the gain of 15 min reported in the ECR, as some gain is still possible with an optimization of the ramp-down cycle for RQ4.R2B1 presently designed to be in the shadow profiting of the long discharge time of IR2 and IR8 triplets. . O. Brüning stated that the TCC approves the ECR.

ACTION: the parameter table in the TCC webpage should be updated with the new parameters.

I. Bejar Alonso announced that there are still several open ECRs, to be finalized before the C&S review, in particular some are following Space Modification Requests.

Modification of the shielded beam screen design – M. Morrone - slides

M. Morrone illustrated the new beam screen concept. During a quench without firing CLIQ, the forces exerted on the beam screen develop towards the cold bore. With the introduction of CLIQ alternating forces are produced, generating a torque within each beam screen quarter containing a tungsten block. The pin designed to center the tungsten block would experience such torque and be bent. It is therefore proposed to have a modification of the pin design. The change implies modifying the geometry of the tungsten blocks, doubling the number of pins and adding reinforcement plates for the Q1 beam screen only.

M. Morrone described the effects of misalignments of the beam screen within the cold bore, i.e. the whole beam screen assembly becomes not self-balanced anymore. In particular, a net torque is generated if the beam screen is misaligned on the x-axis, while a net force towards

the centre is generated if the beam screen is misaligned at a 45 ° angle. The misalignment effects are deemed not to be significant for the fixed point of the beam screen.

The cost impact of the described modification has been quantified to be 250 kCHF, no impact is instead expected in terms of schedule.

P. Ferracin asked what is the maximum radial displacement of the cold bore. M. Morrone explained that in the worst case it is 1.5 mm, in the best case 1 mm, to be verified with the tests.

O. Brüning asked what is the risk of having a contact between the tungsten block and the cold bore and how one can ensure that the structure goes back in the original position after a quench. M. Morrone stated that contact with the cold bore does not pose any problem during a quench and that the tungsten block goes back in position due to the design of the pin. Moreover, M. Morrone says that the design is made to be elastic and cope with the displacements induced during a quench, to be confirmed by the tests.

O. Brüning stated that the TCC approves the ECR, but a presentation should be given on the outcomes of the tests in June.

Cost and manpower estimate for hollow e-lens test stand – A. Rossi - slides

A. Rossi recalled the concept of hollow e-lenses and presented the currently proposed design scheme. She highlighted the differences with existing e-lenses in other facilities. The CERN design will adopt higher electron current and current density and a higher energy. Possible instabilities of the electron beam could be observed and develop over the length of the e-lens due to self-induced electric fields. Understanding of this phenomenon is one of the reasons for having a test stand at CERN.

A. Rossi recalled the plans for the test facility at CERN, consisting of two phases:

Scope of Phase 1:

- E-gun characterization (in parallel or after FNAL).
- Test and commissioning of BGC

Scope of Phase 2:

- Test RF modulation.
- Test BPM for electrons (HF or LF modulation).
- Feedback to vacuum chamber geometry.
- Test resolution of BGC for compressed beams
- Gain experience for the final commissioning: train technicians & engineers to run such a system ready for reception of the final systems
- Test final DAQ & control for many systems
- Investigate electron beam dynamics and benchmark simulation codes like CST, WARP, UltraSAM

The cost for phase 1 is 350 kCHF, already financed by WP13 with a contribution of 50~kCHF from the WP5 R&D budget on hollow e-lenses, including manpower. For phase 2, comparable costs were estimated for the purchase of new solenoids (530 kCHF) and the use of recuperated magnets (520 kCHF). The modulator was not included in the first estimates.

O. Brüning pointed out that the instability build up could not be observed in the test stand. R. Jones commented that there might be configurations that can induce the instability, then those can be taken as a reference to validate simulations for future extrapolations.

O. Brüning asked about the need for an additional modulator for phase 2, R. Jones explained that two different modulators are needed for the assessment of the BPM accuracy. The latter requires higher frequency modulators.

M. Martino asked if support of WP6b would be required for powering, A. Rossi commented this should not be needed.

L. Rossi asked if it would be possible to wait for the first full prototype/spare and then exercise with it to validate all parameters, before the installation or operation in the machine. R. Jones commented that before putting the e-lens in the machine, some test would still be required, as done for other HL systems. He then proposed to look for other facilities where the tests could be performed, but the cost for this is still not covered by the budget.

One possibility could be to do the magnetic part of the tests in SM18. M. Bajko commented that the project should clarify what are the priorities for SM18 tests. O. Brüning mentioned that the e-lens tests could be done after the string tests and that the costs for this should be evaluated. M. Martino added that the tests should also include the powering controls part to be fully representative of real operation.

O. Brüning added that a clarification is needed on when would be the latest time to decide on building the test stand that would still allow to have the possibility to modify the design. In addition, the argument of training of personnel on the use of the e-lens is valid, this opens the possibility for financing via the OP budget.

Cost and manpower estimate for hollow e-lens for HL-LHC – S. Redaelli - slides

S. Redaelli recalled the evolution of the cost estimate for the hollow e-lens since 2016. He then presented the scope of the project, which is the construction and installation of two operational hollow e-lenses and the procurement of spare components for a third lens. The e-lens would be installed in point 4 and deployed in LS3 for operation in Run 4. The present design features two solenoids to accommodate the gas curtain monitor in the center.

S. Redaelli presented the budget table, highlighting a total cost of 10.46 MCHF. L. Bottura asked if the magnets are considered to come fully from in-kind contributions. O. Brüning confirmed this is the case, MSC should only take care of following up the in-kind contribution. The tests shall be done in an institute or company.

F. Bertinelli pointed out that about 4.8 MCHF coming from in-kind contributions is from different institutes, so the costs for the possible final assembly at CERN should be included in the estimates.

P. Fessia asked if the cost for orbit correctors is included in the estimates. S. Redaelli pointed out that it is kept as an option, as the possible use has to be defined also according to the operating mode of the e-lenses, for example they might be switched ON only at the end of the ramp. On the other hand, his preferred solution really is to have the dipole. He commented that D. Perini has come up with a first design where this dipole is incorporated in the present design, with minor cost and integration impacts.

O. Brüning proposed to keep the test stand as an option. If the hollow e-lens is approved as baseline then one should look for in-kind contributions. L. Rossi encouraged all groups to explore the possibility to have in-kind contributions, when possible. S. Redaelli commented that this approach is also in line with the outcome of the October 2017 review and he suggests not to change strategy so shortly before the C&S review.

O. Brüning recommended all WP leaders to provide Stefano with comments on the budget table. M. Martino commented that the cost estimate for power converters is already optimized, as it is based on the same design developed for HL-LHC. P. Fessia asked S. Claudet to clarify what could be the possible cost saving for the cryogenics. S. Claudet explained that the synergy with other activities could be exploited in this case in order to share the costs, i.e. for the modification of the QRL and an additional jumper in Pt4. The possibility to recover some equipment from points 1 and 5 will also be explored. L. Rossi encouraged Serge to explore possibilities to have in-kind contributions from France for the cryogenics equipment.

F. Bertinelli pointed out that removing the spare module from the cost estimate would save 1 MCHF. L. Rossi commented that it is a choice of the project to always include spare equipment in the total costs for new HL systems (however spares are counted in a special HL CONS budget)..

Outstanding project options – O. Brüning - slides

O. Brüning reviewed the list of open project options in view of the upcoming C&S review. The list divided in five categories: 1) machine protection and risk mitigation, 2) facilitating HL-LHC interventions, 3) additional diagnostics, 4) mitigations against unforeseen performance limitations, 5) additional performance improvement.

Options in category 1):

- MKB or TDE upgrade (WP14): this option is still valid and is actually increased in scope (6.4 + 1 MCHF full cost estimate). P. Fessia asked if the costs could not be covered from the consolidation budget. C. Bracco explained that in LHC Run 3 we might already be at the limit of tolerable energy deposition in the dump windows, which will be mitigated introducing the retriggering of the dilution kickers. In addition, TCDQ (not in baseline) and TCDS (already in baseline) are also critical for LIU beams due to existing non-conformities, a strategy needs to be defined in 2020. So probably a share

with LHC CONS is possible.
- MKI upgrade (WP14): now in the baseline.
- TCDQ and BETS upgrade (WP14): this is a new option. L. Rossi asked why this option was later re-introduced. G. Arduini and C. Bracco explained that the upgrade would be mainly needed in Run 3 for the LHC ATS flat optics while at present there is no clear evidence that it is required for HL-LHC. L. Rossi suggested removing it from the option list, but to keep it as an open issue, maybe to be covered by the consolidation budget. C. Bracco added that nevertheless this option would be ready in LS3, it is impossible to have it in LS2.
- Cold diodes (WP3, WP7): this is a new option.
- Beam halo depletion devices (WP5): the hollow e-lens will be proposed as a new baseline element. O. Brüning suggested presenting the test stand as an option (possibly covered by OP budget) and verifying the cost for testing in SM18 (M. Bajko).
- Rotatable collimators (WP5): no longer pursued.
- Additional 11T magnet and DS collimation units: no longer pursued.

Options in category 2):

- Laser Engineered Surface Structures (WP12): still valid option, together with the evaluation of the possibility to coat all quadrupoles in the matching sections
- Remote controlled alignment (WP2, WP3, WP5, WP7, WP8, WP9, WP10, WP12, WP13, WP15): new hardware option, too early to be proposed as baseline, all cost implications should be evaluated.

Options in category 3):

- Full implementation of the Beam Gas Vertex Detector (WP13) is now in the baseline.
- Second undulator for BSRT (WP13), to have monitoring of the beam halo during the full cycle (from injection energy), this is still a valid option. L. Rossi commented that this halo monitor is strictly linked to the presence of the hollow e-lens. S. Redaelli disagreed and clarified that the needs of hollow e-lenses are mainly driven by collimation requirements at top energy, where the halo monitoring is covered by the coronograph. R. Jones explained that it is not only for that, but also for long range beam-beam measurements and it is relevant for machine protection as a halo detector (35 MJ tails). Y. Papaphilippou added that understanding the tail population in a non-invasive way is already very important, independently of the presence of the e-lens. L. Rossi commented that as it is a relevant item already for Run 3 operation, this must be covered by the consolidation budget.
- Inclinometer for vibration measurements, only pursued as a study, not anymore considered an option.

Category 4):

- Wideband feedback system (WP4) no longer pursued as an option, but would like the design for pickup and kicker by the RF group to continue to estimate the impedance

impact by WP2.

- Additional RF systems (WP4): the 800 MHz option was eliminated in 2017, there's no strong evidence for the need of the 200 MHz option, which could maybe be considered for LS4, as HL-LHC consolidation.
- LRBB compensation (WP13): very encouraging results from wire-in-jaw collimators from MDs, this is kept as an option. The e-beam compensator is no longer pursued instead.
- Additional Dispersion Suppressor collimators (WP5), no longer pursued.
- Additional low-impedance collimators in IR3, no longer pursued.
- New tertiary collimator for IR2 and 8 (WP5) no longer pursued by HL-LHC, but covered by the consolidation project (possible in-kind contribution from Russia).
- Higher precision current control for power converters (WP6b): this is a new option, which is a mitigation against the increase of tune fluctuation due to ATS optics, possibly leading to an unbalance of the delivered luminosity between the experiments.
- Installation of the second half of the Crab Cavities (WP4), no longer pursued. G. Arduini confirmed that the integrated performance loss is in the order of a few percent, the main reason for the additional crab cavities was for the crab kissing scheme. P. Fessia added that no change of civil engineering is foreseen following this choice, so there's no major saving associated. L. Rossi commented that since this option is closed, no space reservation in the tunnel is guaranteed anymore.

Category 5):

- Crystal collimation is still a valid option (WP5) for ion operation, this is proposed as in-kind contribution from Russia. L. Rossi asked if this could be a viable option for protons. S. Redaelli explained that it is not possible due to the excessive power, unless major modifications of IR7 would be applied. He added that the decision on implementation for ions has to be taken after the 2018 ion run. A detailed cost estimate is needed but it is expected that for the ion case, one can stay below the 1.5~MCHF figure presented by Oliver.
- MQ4 as MQYY no longer pursued (WP3), a part from ongoing activities of QUACO and the CEA contract. G. Arduini mentioned that aperture is recovered with the full remote alignment option. M. Martino asked if the Q4 600 A correctors are also removed from the baseline as a consequence. O. Brüning confirmed this is the case.
- RF quadrupole (WP4), no longer pursued
- Stochastic cooling for ions, no longer pursued
- Operation with crossing angle plane exchange is no longer pursued, while operation with variable crossing angle during beta* levelling is a viable operation option
- For parameters and machine configurations, flat beam operation, the 8b4e filling scheme, the 80 bunch PS filling scheme and the BCMS filling scheme are all assumed as valid operation options; the crab kissing scheme and long bunch length operation are no longer pursued due to the absence of additional crab cavities and the 200 MHz RF system, respectively. G. Arduini pointed out that for the validation of the 80 bunch PS filling scheme transfer lines and injection protection with 320 bunches per injection

should be verified by WP14. L. Rossi suggested documenting parameters for alternative filling schemes and scenarios in a dedicated table. G. Arduini commented that for flat beams the minimum achievable crossing angle should still be demonstrated.

O. Brüning announced the next HL-LHC TCC meeting, scheduled on 5th April.